Document made available under the Patent Cooperation Treaty (PCT)

International application number: PCT/GB05/000739

International filing date: 28 February 2005 (28.02.2005)

Document type: Certified copy of priority document

Document details: Country/Office: GB
Number: 0404231.3
Filing date: 26 February 2004 (26.02.2004)

Date of receipt at the International Bureau: 09 May 2005 (09.05.2005)

Remark: Priority document submitted or transmitted to the International Bureau in compliance with Rule 17.1(a) or (b)

World Intellectual Property Organization (WIPO) - Geneva, Switzerland
Organisation Mondiale de la Propriété Intellectuelle (OMPI) - Genève, Suisse

PCT/GB 2005 / 000739

The Patent Office
Concept House
Cardiff Road
Newport
South Wales
NP10 8QQ

I, the undersigned, being an officer duly authorised in accordance with Section 74(1) and (4) of the Deregulation & Contracting Out Act 1994, to sign and issue certificates on behalf of the Comptroller-General, hereby certify that annexed hereto is a true copy of the documents as originally filed in connection with the patent application identified therein.

In accordance with the Patents (Companies Re-registration) Rules 1982, if a company named in this certificate and any accompanying documents has re-registered under the Companies Act 1980 with the same name as that with which it was registered immediately before re-registration save for the substitution as, or inclusion as, the last part of the name of the words "public limited company" or their equivalents in Welsh, references to the name of the company in this certificate and any accompanying documents shall be treated as references to the name with which it is so re-registered.

In accordance with the rules, the words "public limited company" may be replaced by p.l.c., plc, P.L.C. or PLC.

Re-registration under the Companies Act does not constitute a new legal entity but merely subjects the company to certain additional company law rules.

Signed

Dated 7 April 2005

Patents Form 1/77

Patents Act 1977
(Rule 16)

The Patent Office

26FEB04 E876273-1 C47904
P01/7700 0.00-0404231.3 ACCOUNT CHA

THE PATENT OFFICE
J
26 FEB 2004
NEWPORT

Request for grant of a patent

(See the notes on the back of this form. You can also get an explanatory leaflet from the Patent Office to help you fill in this form)

The Patent Office

Cardiff Road
Newport
South Wales
NP10 8QQ

1. Your reference	X412
2. Patent application number *(The Patent Office will fill in this part)*	0404231.3 — 26 FEB 2004
3. Full name, address and postcode of the or of each applicant *(underline all surnames)*	Xaar Technology Limited, Science Park, Cambridge, CB4 0XR
Patents ADP number *(if you know it)*	7301872003
If the applicant is a corporate body, give the country/state of its incorporation	UK
4. Title of the invention	Droplet Deposition Apparatus
5. Name of your agent *(if you have one)* "Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*	~~Xaar Technology Limited, Science Park, Cambridge, CB4 0XR~~ Mathys & Squire 100 Gray's Inn Rd LONDON WC1X 8AL
Patents ADP number *(if you know it)*	1081001
6. If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and *(if you know it)* the or each application number	Country — Priority application number *(if you know it)* — Date of filing *(day / month / year)*
7. If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application	Number of earlier application — Date of filing *(day / month / year)*
8. Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer 'Yes' if: a) any applicant named in part 3 is not an inventor, or b) there is an inventor who is not named as an applicant, or c) any named applicant is a corporate body. See note (d))*	YES

9. Enter the number of sheets for any of the following items you are filing with this form. Do not count copies of the same document

Continuation sheets of this form	---
Description	10
Claim *(s)*	2
Abstract	---
Drawing *(s)*	~~5~~ 5 8

10. If you are also filing any of the following, state how many against each item.

Priority documents	---
Translations of priority documents	---
Statement of inventorship and right to grant of a patent *(Patents Form 7/77)*	---
Request for preliminary examination and search *(Patents Form 9/77)*	---
Request for substantive examination *(Patents Form 10/77)*	---
Any other documents *(please specify)*	---

11. I/We request the grant of a patent on the basis of this application.

Signature Nick Rob Date 25/2/2004

12. Name and daytime telephone number of person to contact in the United Kingdom — Nick Roberts 01223 423 663

Warning

After an application for a patent has been filed, the Comptroller of the Patent Office will consider whether publication or communication of the invention should be prohibited or restricted under Section 22 of the Patents Act 1977. You will be informed if it is necessary to prohibit or restrict your invention in this way. Furthermore, if you live in the United Kingdom, Section 23 of the Patents Act 1977 stops you from applying for a patent abroad without first getting written permission from the Patent Office unless an application has been filed at least 6 weeks beforehand in the United Kingdom for a patent for the same invention and either no direction prohibiting publication or communication has been given, or any such direction has been revoked.

Notes

a) *If you need help to fill in this form or you have any questions, please contact the Patent Office on 08459 500505.*

b) *Write your answers in capital letters using black ink or you may type them.*

c) *If there is not enough space for all the relevant details on any part of this form, please continue on a separate sheet of paper and write "see continuation sheet" in the relevant part(s). Any continuation sheet should be attached to this form.*

d) *If you have answered 'Yes' Patents Form 7/77 will need to be filed.*

e) *Once you have filled in the form you must remember to sign and date it.*

f) *For details of the fee and ways to pay please contact the Patent Office.*

DUPLICATE

Droplet Deposition Apparatus

The present invention relates to droplet deposition apparatus and in particular drop on demand ink jet printing apparatus.

In the field of inkjet printing, image quality is often measured in terms of dots per inch (dpi) where the higher the number of dots the better the image. Whilst this is a general rule of thumb it is not true in all cases. For example, the dots may be of such a size that decreasing the spacing between them will make no improvement to the image quality. In fact, in these situations the quality may be reduced since excess ink is deposited that causes bleeding, cockling and strikethrough.

The majority of commercially available inkjet printers are capable of depositing a single dot size. However, the quality of an image, as perceived by the human eye, is improved by depositing variable sized droplets rather than just single sized droplets. The technique of depositing variable sized drops is known in the art as greyscale.

A print head that is capable of printing with 15 different drop sizes at a resolution of 360dpi can produce an image that, to the human eye, will appear to have a better quality than an identical image printed in binary at 720 or even 1440dpi.

These higher dpi images must be created by repeatedly passing a print head over a substrate. Dots deposited on each pass are interleaved with

previously printed dots. Since each pass takes a finite time to complete the time required to print an image is increased in proportion with the number of passes.

Certain print head constructions are capable of printing images at 360dpi. Such a print head is exemplified in JP 04-259 563. Two actuators having a natural density of around 180dpi are mounted on either side of a substrate in an offset arrangement to provide a print head having a natural resolution of 360dpi. Such a print head is commonly known as a "back to back" actuator.

The ease at which actuators may be stacked to form a higher resolution print head is dependant on the natural resolution of the actuators. At 180dpi a drop is deposited on the paper every 140μm and at 360dpi a drop is deposited every 70μm. Two 180dpi actuators stacked to deposit an image at 360dpi must ensure that droplets are deposited at regular and uniform 70μm spacing. Failure to align the droplets correctly creates deficiencies in the quality of the image produced; for example lighter and darker bands may be being visible in an image error is commonly known as banding. A small tolerance either way of the optimum spacing is acceptable, however, and does not visibly affect the quality of the image. This tolerance is typically +/- 15μm in a 360dpi head.

In the case where two 360dpi actuators are stacked to give a 720dpi image each ejected droplet should be arranged at a regular spacing of the order 35μm. In this arrangement the tolerance on the spacing is reduced to around + / - 7μm.

Alignment is made more simple by ensuring the substrate to which the actuators are attached is slim – a thicker substrate can increase optical alignment errors.

One further issue for back to back actuators is one of thermal management. The actuator and the integrated circuits generate heat during operation of the print head, the integrated circuits being the major contributor to heat generation in a piezoelectric print head. For print heads utilising resistive heating to generate bubbles the major source of heat generation is the resistive elements themselves.

Looking in particular at a piezoelectric print head that comprises PZT, PZT is a poor conductor of heat and can easily be cracked and damaged where there is a significant rise in temperature of the print head and where a mismatch in the coefficient of thermal expansion (CTE) is present between different components in the head and between the support and the actuators.

The temperature of a print head must also remain at a constant temperature during operation to avoid temperature dependent printing defects caused, for example, by variations in viscosity of the ink due to temperature fluctuations.

Where a single row, i.e. non back to back print head is used, there is no real limit to the thickness of the base supporting the actuators. Therefore, this can be designed to be sufficiently large so as to absorb and conduct heat away from the actuator elements thereby minimising temperature variations.

In a back-to-back architecture there is double the heat generation than in a single row print head as there are double the number of actuators and chips. As discussed above, it is desirable to minimise the thickness of the support to aid manufacture but any reduction in thickness reduces the volume of material available to transfer heat away from the actuators.

The present invention seeks to address this and other problems.

Thus, according to one aspect of the present invention there is provided droplet deposition apparatus comprising a thermal management support having two opposing surfaces, each of said surfaces having at least one actuator mounted thereon; wherein said thermal management support comprises an internal cavity, and fluid ports arranged on the exterior of said support and communicating with said internal cavity for supply and circulation of fluid through said internal cavity.

Preferably the support is formed of a material having a high coefficient of thermal transfer. A particularly preferred material is a thermally conductive plastic, but other materials such as metals may also be appropriate.

Preferably the support is formed of multiple parts, said parts being combined to define the interval cavity. The multiple parts may be formed by moulding, or some other method and preferably the surfaces to which the actuators are mounted are machined to a required flatness. The surfaces preferably being machined after the multiple parts have been combined.

The internal cavity preferably comprises separator means thereby dividing said internal cavity into a first channel for providing thermal management for said actuators and a second channel for providing thermal management for integrated circuits mounted on said support. The divider means may be a wall, the relative dimensions of each channel preferably being chosen to provide an appropriate flow of fluid to either the integrated circuits or actuators depending on which generates the greater heat energy.

Preferably the fluid is water though a gas or another liquid may be appropriate. The inlet temperature of the fluid may be kept constant.

Alignment features may be formed or provided on the exterior surface of the support to aid alignment of the actuators or other components mounted on thereon.

Preferably the thickness between the mounting surfaces is less than 5mm, more preferably less than 3mm and even more preferably of the order 2mm.

The present invention will now be described, by way of example only, with reference to the following diagrams in which:

Figure 1 shows a piezoelectric printer of the prior art having a single array of channels

Figure 2 shows in section a back to back actuator of the prior art

Figure 3 a to c depicts a top, rear and side view respectively of a support according to the present invention.

Figure 4 depicts the internal features of the support provided by a first component of the support.

Figure 5 depicts the internal features of the support provided by a second component of the support.

Figure 1 depicts a printhead of the prior art. Channels 6 are formed in a sheet of piezoelectric material 2 which is polarised in the direction of the arrow P. The walls 8,10 which separate the channels have electrode material applied to them such that a voltage applied between the electrodes can cause the walls to deflect in shear. This initiates a pressure wave in the ink contained the channel the pressure wave converging at a nozzle formed in the nozzle plate 4 to produce droplet ejection. The electrodes are connected to tracks 18 which are further connected to driver chips (not shown).

At the rear of the actuator a chassis 16 is provided that contains electric tracks 18. The tracks are wire bonded 20 to the electrodes on the walls 8,10 to form an electrical connection. In alternative arrangements, the chassis 16 extends below the channelled component 10 and acts as a support for the piezoelectric material.

The tops of the channels are bounded by a cover plate 12 having an aperture 14 that acts as an ink manifold and allows the fluid to enter the channels. The active length of the channel being the distance travelled by the

acoustic wave in the ink is determined by the length of the portion of the cover plate and is denoted by the letter L.

The top of the ink manifold 14 is attached to a tube (not shown) with the opposite end attached to a reservoir (not shown).

A nozzle plate 14 is attached to the front face of the actuator and contains nozzles (not shown), one per channel.

The mechanisms of droplet ejection from printheads of this type are well documented in the prior art and consequently will not be discussed in any further detail in the present application.

Back to back actuators are known in the prior art as depicted in Figure 2. The actuators are each formed from layers of piezoelectric material. Layers 30,31 and 35,36 are polarised in opposite directions as shown by the arrows P and laminated together to form sheets. These sheets are bonded to opposite sides of a central support 40. Channels 6 are sawn into the sheets and an electrode material 38 deposited on the defining surfaces of the dividing wall. The channels are closed by a cover 32, 37 and a nozzle plate formed with nozzles is subsequently attached to the front surface of the print head.

Figure 3 a to c depicts a substrate according to the present invention. The substrate consists of a laminate of moulded components and has a number of functional features.

Towards the front of the substrate there are found parallel mounting surfaces 50a, 50b, spaced apart a distance of the order 3mm in a direction

perpendicular to the plane of the surfaces. A tighter tolerance on the distance between the surfaces is achieved through a machining step where one or both mounting surfaces are mechanically or chemically machined to provide flatter surfaces. The present invention enables machining of the mounting surfaces without needing to machine other portions of the support.

Each surface has a length of the order 68mm and a breadth of the order 14mm and an area of the order 10cm^2. These dimensions are sufficient to mount a shear mode, shared wall piezoelectric droplet deposition apparatus having around 350 channels, an active length of 1mm and capable of firing 15 different drop sizes.

A second planar portion 52a, 52b adjacent to the mounting surfaces provides a holding surface suitable for holding a printed circuit board. Integrated circuits may be bonded directly to the substrate or may be mounted on the printed circuit board.

Wings 54 are provided at the side edges of the support and are provided with datum features and features to enable mounting of the print head into a printer. The wings are visible throughout manufacture and in the completed head and can be provided with a bar code or some other marking device that can contain information about the head.

Ports 56 are provided to the rear of the support and allow coolant fluid, preferably water, to be circulated through an internal cavity in the support. The

large upper and lower surfaces 50, 52 of the support ensure that the majority of the heat generating components can be efficiently cooled by the coolant fluid.

The material of the component parts is a thermally conductive plastic, known as Coolpoly and commercially available from Coolpolymers, Inc. The plastic provides good thermal conductivity of between 1.2 W/mK and 20 W/mK depending on the material chosen and is mouldable enabling external features described above and internal features described later to be cheaply and quickly manufactured. The ability to machine portions requiring higher tolerances that that which may be achieved by moulding is advantageous.

By moulding the component parts separately and joining together it is possible to provide internal features to the support that aid alignment of the two components, provide fluid seals and / or ensure a desired flow path of liquid through the support. By moulding and combining it is also possible to form narrow internal channels that allow the thickness of the support to be minimised.

Figure 4 depicts the internal features of the support provided by a first component of the support. The component comprises a projection 60 that extends around the periphery of the fluid containing portion 62. The projection mates with a groove provided on the second component that forms the support and with the aid of an adhesive ensures a fluid-tight seal. Further projection portions 64 aids alignment of the components to each other.

A barrier portion 66 within the fluid containing portion divides an actuator-cooling channel 68 from a chip-cooling channel 70. The relative size of each of these channels and consequently the proportion of fluid flow through each of these channels is dependent on ratio of the relative heat generation of the chip and actuator. For a piezoelectric print head, as in this embodiment, the majority of the generated heat is provided from the chips and hence the chip cooling channel has a greater dimension than the actuator cooling channel.

Figure 5 depicts the second component of the substrate. It is substantially the same as the first component with the exception that where projections are formed for the first component, complementary mating grooves 60a, 64a are provided in the second component.

Whilst the above invention has been described with reference to a single actuator component bonded to either surface it will be appreciated that multiple actuator components may be bonded to both surfaces.

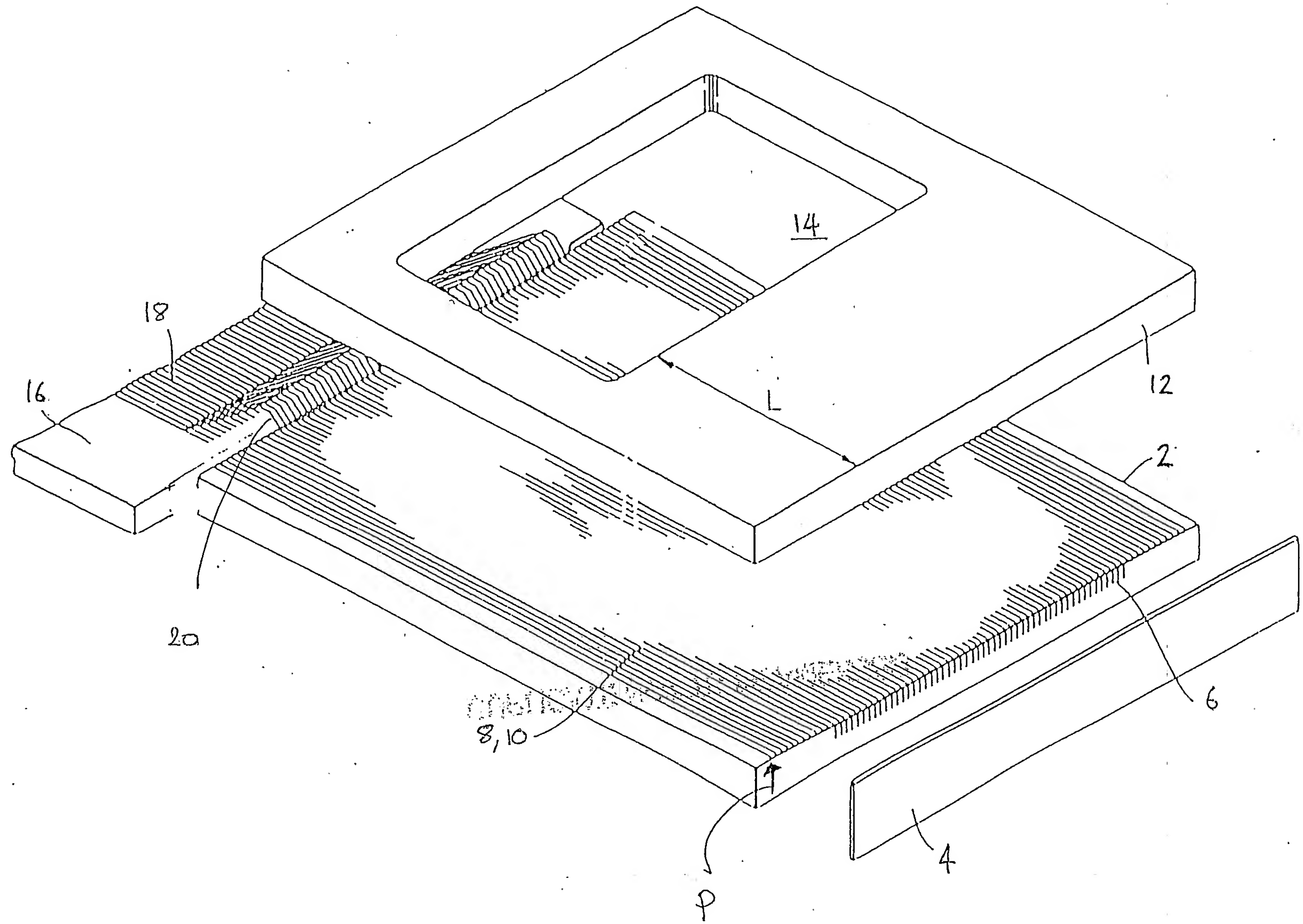
Each feature described in the diagrams, description or claims may be incorporated into the claims either individually or in combination with any other feature of features described herein.

Claims

1. Droplet deposition apparatus comprising a thermal management support having two opposing surfaces, each of said surfaces having at least one actuator mounted thereon; wherein said thermal management support comprises an internal cavity, and fluid ports arranged on the exterior of said support and communicating with said internal cavity for supply and circulation of fluid through said internal cavity.
2. Apparatus according to Claim 1, wherein said support is formed of a material having a thermal conductivity greater than 1.2. W/mK.
3. Apparatus according to Claim 1 or Claim 2, wherein said support is formed of a thermally conductive plastic.
4. Apparatus according to Claim 1 or Claim 2, wherein said support is formed of a metallic material.
5. Apparatus according to any preceding claim, wherein said support is formed from multiple parts, said parts combining to define said internal cavity.
6. Apparatus according to Claim 5, wherein said multiple parts are formed by moulding.
7. Apparatus according to any preceding claim, wherein said surfaces are machined surfaces.
8. Apparatus according to Claim 7, when dependent upon Claim 5 or Claim 6, wherein said surfaces are machined after combination of said multiple parts.

9. Apparatus according to any preceding claim, wherein said internal cavity comprises separator means thereby dividing said internal cavity into a first channel for providing thermal management for said actuators and a second channel for providing thermal management for integrated circuits mounted on said support.
10. Apparatus according to Claim 9, wherein the second channel has a greater volume than the first channel.
11. Apparatus according to any preceding claim, wherein said thermal management is to provide cooling.
12. Apparatus according to any one of Claim 1 to Claim 10, wherein said thermal management is to provide heating.
13. Apparatus as substantially hereinbefore described with reference to Figures 3 to 5.

Fig.1. - Prior Art



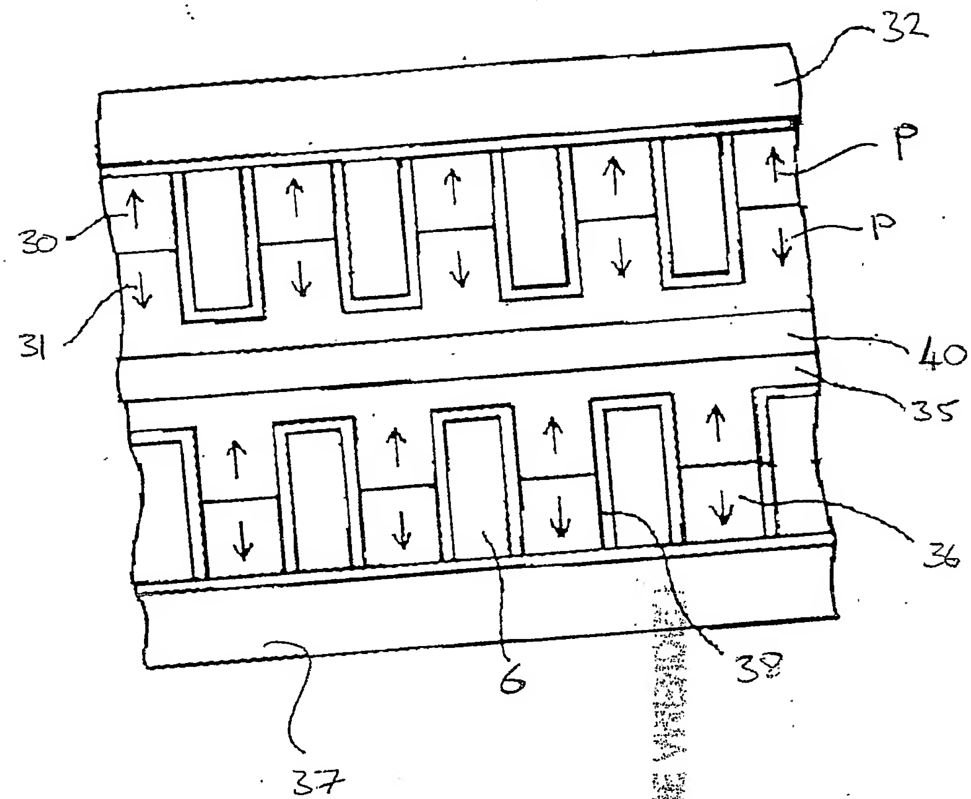


Figure 2

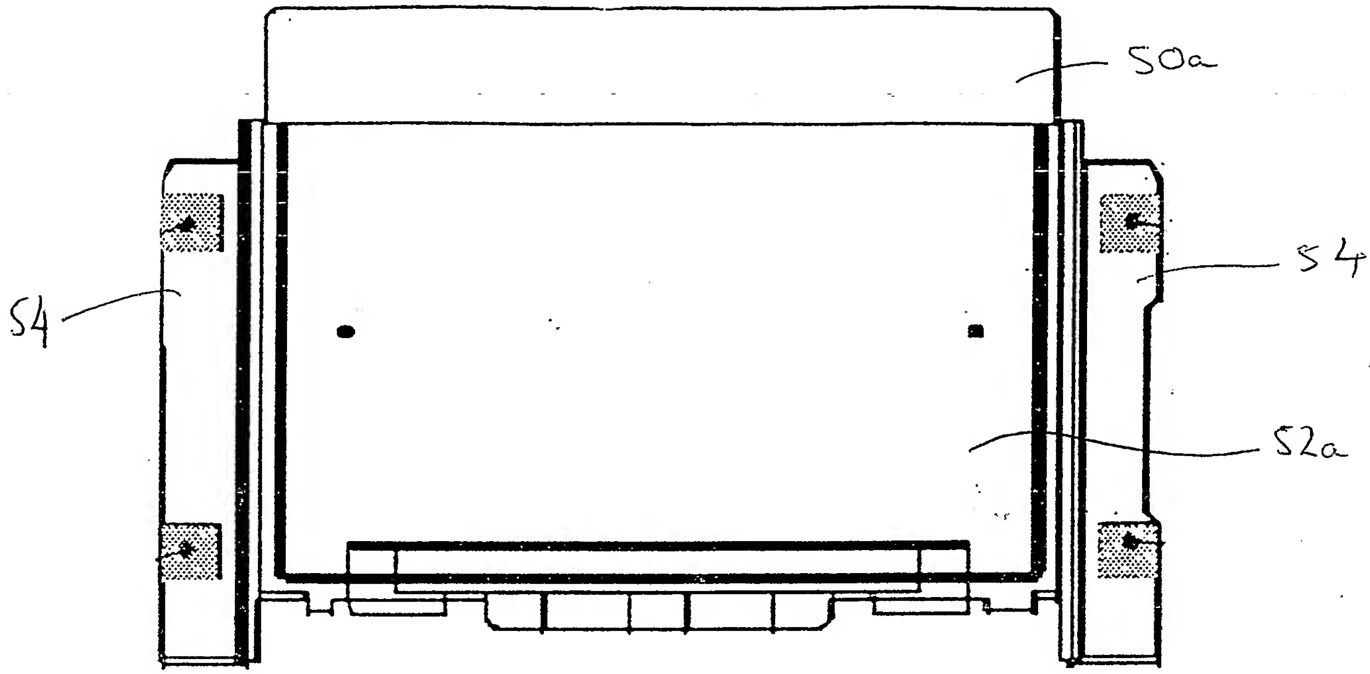


Figure 3a

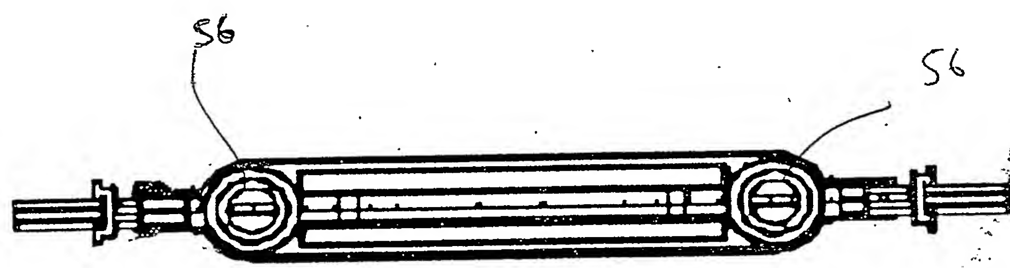


Figure 3b

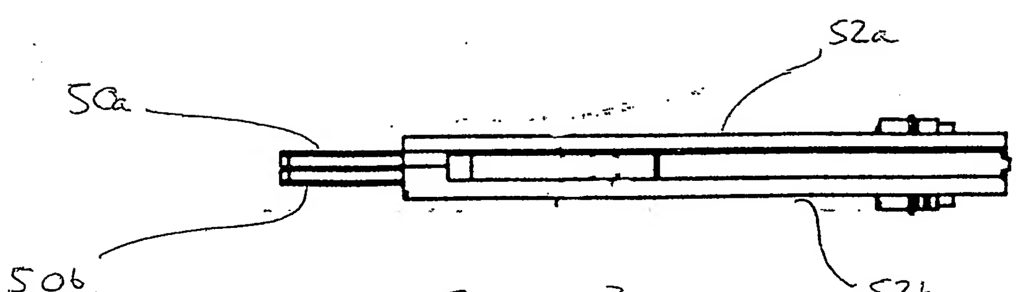


Figure 3c

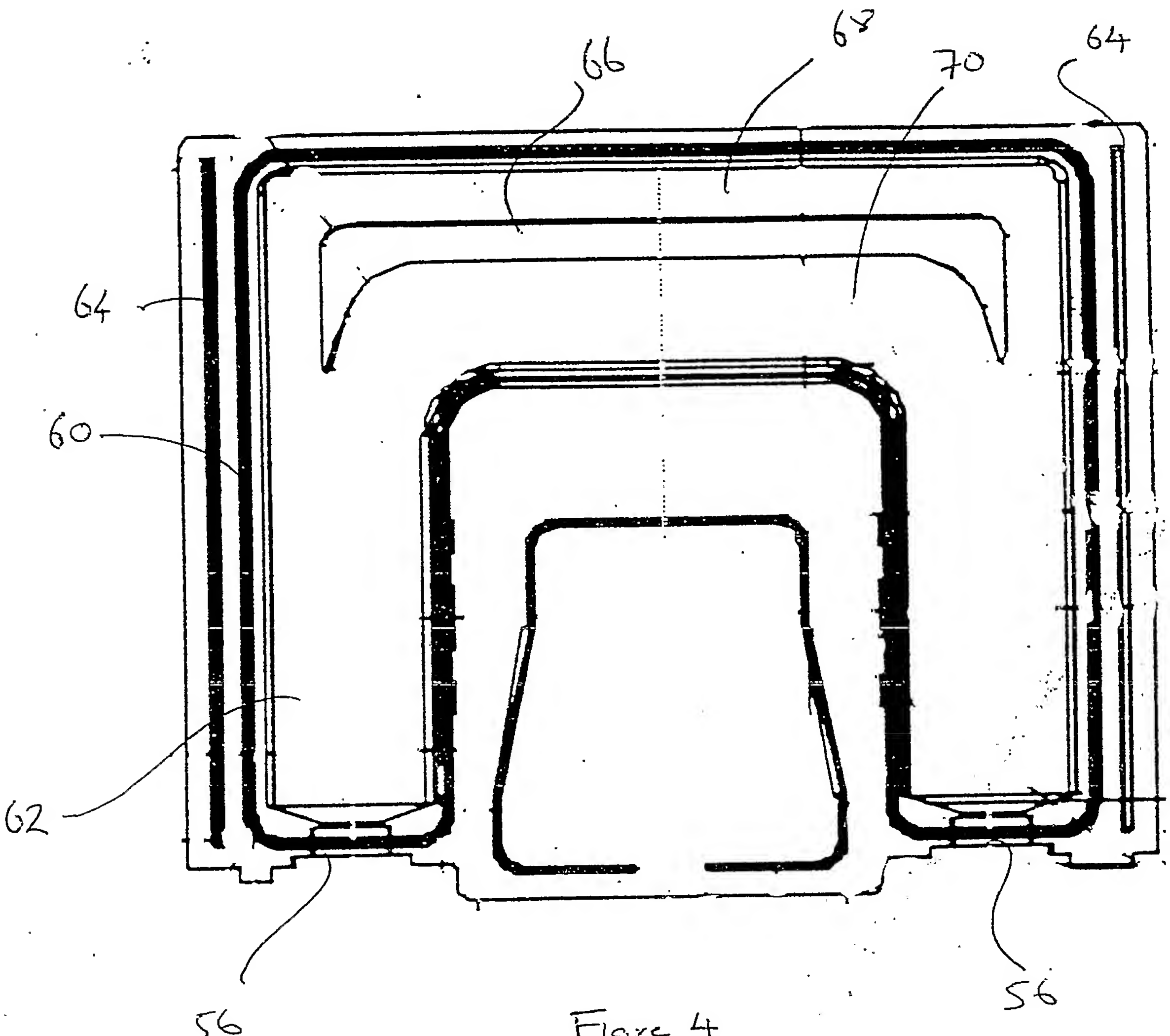


Figure 4.

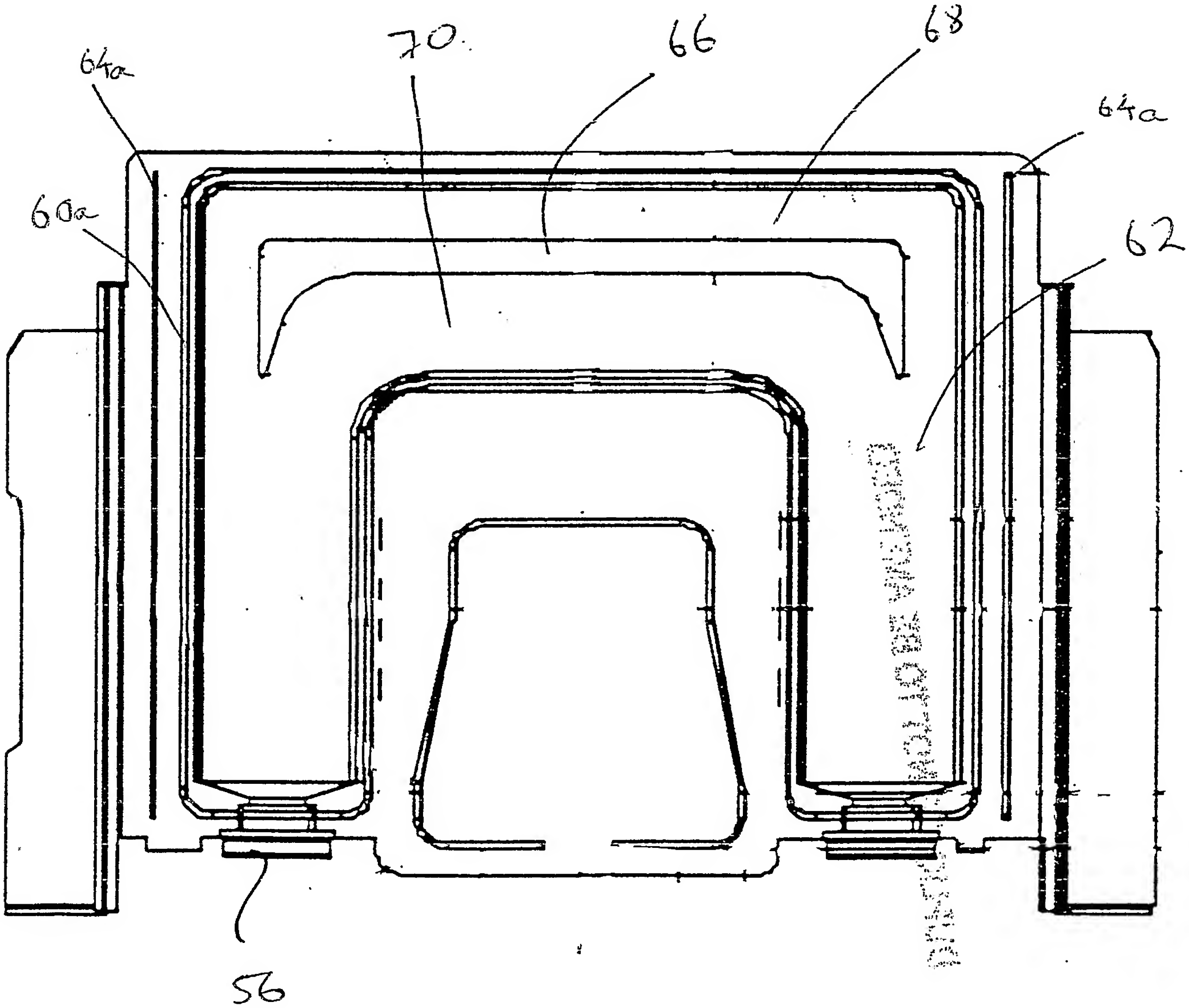


Figure 5